

Roadmap for Performance-Based Navigation

*Evolution for Area Navigation (RNAV) and
Required Navigation Performance (RNP) Capabilities
2006-2025*

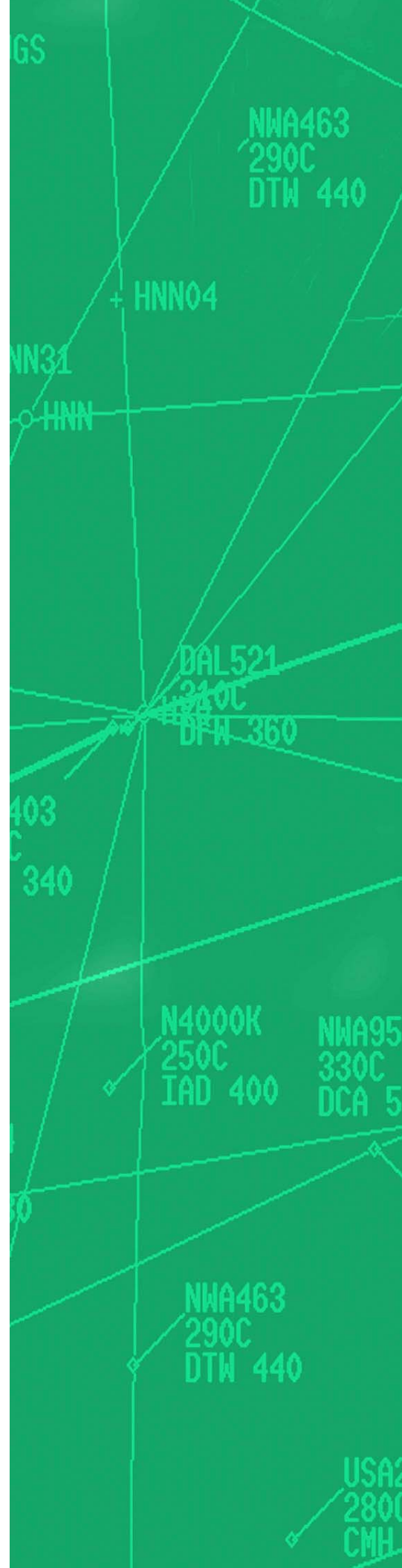
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Purpose and Background

Originally published in July 2003, the *Roadmap for Performance-Based Navigation* is intended to assist aviation stakeholders in understanding operational goals, determining requirements, and considering future investments. The *Roadmap* focuses on addressing future efficiency and capacity needs while maintaining or improving safety of flight operations, by leveraging advances in navigation capabilities on the flight deck. This revision updates the FAA and industry's overall strategy for the evolution towards performance-based navigation.

Like the first edition of the *Roadmap*, this update has been coordinated with the aviation community through government-industry forums including the Performance-Based Operations Aviation Rulemaking Committee (PARC) and RTCA. Since 2003, extensive coordination on performance-based navigation standards and issues has been conducted with our international partners through various forums such as the International Civil Aviation Organization (ICAO), EUROCONTROL, and the North American Aviation Trilateral (NAAT) as well as through a number of bilateral partnerships. For example, this updated *Roadmap* is harmonized with ICAO's development of a new *Performance-Based Navigation Manual*, and reflects some changes to achieve common international operations.

This *Roadmap* provides a high-level strategy for the evolution of navigation capabilities to be implemented in three timeframes: near term (2006-2010), mid term (2011-2015), and far term (2016-2025). This strategy includes two key navigation concepts: Area Navigation (RNAV) and Required Navigation Performance (RNP), and encompasses instrument approaches, Standard Instrument Departure (SID) and Standard Terminal Arrival (STAR) operations, as well as en route and oceanic operations. In the far-term section, integrated navigation, communication, surveillance and automation strategies are discussed.

The *Roadmap* supports other Federal Aviation Administration (FAA) and government-wide planning processes. The FAA is working on several fronts to address the needs of the aviation community. At the forefront is the FAA's *Flight Plan* which is a five-year strategy directing FAA budget requests. For the *Flight Plan* timeframe and beyond, the FAA's Operational Evolution Plan (OEP) addresses capacity and efficiency initiatives over a rolling ten-year period at the busiest 35 airports in the National Airspace System (NAS). The FAA, in a multi-agency collaboration of the Joint Planning and Development Office (JPDO), is developing a plan for the Next Generation Air Transportation System (NGATS) to meet the future air transportation needs through the year 2025. Common to these plans is the goal of adopting satellite-based navigation as a cornerstone for performance-based operations.

Other emerging performance-based concepts are Required Communications Performance (RCP), Required Surveillance Performance (RSP), and Required Total System Performance (RTSP). These concepts define specified levels of performance and capability as agreed-upon standards, while leaving the implementation of solutions and technologies to appropriate aviation stakeholders such as avionics manufacturers, aircraft manufacturers, and air traffic service providers. RNAV and RNP have reached a level of maturity and definition to be included in key plans and strategies, such as this updated edition of the *Roadmap*. RCP definition has also made progress within the PARC since the first edition of the *Roadmap*, and its roadmap is being developed separately. RSP and RTSP are still emerging concepts in the early developmental stages. Together, through collaboration within the FAA and JPDO, these are expected to be more fully defined in the next edition of the *Roadmap*.



FAA Flight Plan

- Five-year strategy plan
- Four thrusts (one is capacity)
- Involves all FAA Lines of Business. The FAA Lines of Business in turn have five-year business plans that support the Flight Plan.



OEP

- Critical plan to address effective capacity
- Rolling 10-year timeframe
- Distills and aligns all commitments needed to deliver critical capacity improvements



NGATS

- Long-term view (2025) of the national air transportation system. Has a broad scope with air traffic management as one facet of the plan.
- Multi-agency involvement
- Aims to transform the system



The aviation community stakeholders to benefit from the concepts in this *Roadmap* include:

- ☐ Airspace operators
- ☐ Air traffic service providers
- ☐ Regulators and standards organizations
- ☐ Airframe and avionics manufacturers

The *Roadmap* is intended to help stakeholders plan their future transition and investment strategies. As driven by business cases, airlines and operators can use the Roadmap to plan future equipage and capability investments. Avionics and aircraft manufacturers can determine the capabilities needed in the future. Similarly, air traffic service providers can determine requirements for future automation systems, and more smoothly implement ground infrastructure modernization. Finally, regulators and standards organizations can anticipate and develop the key enabling criteria needed for implementation.

Aviation System Context

The nation's air transportation system continues to play an essential role in our economy and security, with an historical growth trend expected to continue steadily over the next twenty years. In 2005, passenger demand grew at a fast pace, with enplanements up seven percent from the previous year to 738.6 million and revenue passenger miles increasing eight percent to 775.3 billion. Both major airlines and regional carriers experienced growth in enplanements in 2005, with the fastest growth at regional carriers. International air transportation grew almost twice as fast as domestic markets led by double-digit increases in both the Latin American and Pacific regions. Between 2005 and 2017, air transportation system passenger demand is projected to increase an average of 3.4 percent each year. By 2017, U.S. commercial air carriers are projected to transport a total of about one billion passengers, flying over 1.25 trillion passenger miles. Flights have more passengers, with load factors projected to continue steadily increasing to more than 78 percent by 2017. To support forecasted operational changes, airframe and avionics manufacturers are adding flight deck capabilities that enable advanced navigation and other services.

General aviation continues to show strength and is expected to grow even stronger in the future. The piston aircraft fleet is projected to increase at an average annual rate of 1.4 percent, while a broad variety of business jets are projected to grow in number at an average rate of four percent per year. The introduction of very light jets (VLJ) into the NAS will introduce new complexities and growth at certain airports in the future. These VLJs are projected to increase by as many as 400 to 500 aircraft per year. Adding to airspace and operational complexity, unmanned aircraft systems (UAS) are expected to be used in routine operations in the NAS.

Growth in scheduled and general aviation aircraft is expected to increase point-to-point and direct routing, with the need for system flexibility to handle peaks in traffic demand, convective weather, military operations and security needs. By 2017, traffic will peak at the nation's busiest airports to a level 30-40 percent higher than today, based on the FAA's Terminal Area Forecasts. This amount of traffic will significantly increase delays particularly when unpredictable weather and other factors constrain airport capacity. Diligent effort must be made to increase system flexibility, to improve strategic management of flights, and to control delays while maintaining the safety we experience today.

The cost of fuel is a significant challenge that aircraft users face today, affecting all segments of the aviation community. For example, higher fuel prices cost the air carrier industry nearly \$33 billion in 2005, twice what they spent in 2003. At a consumption rate of nearly 20 billion gallons per year, every penny increase in the price of a gallon of jet fuel raises annual fuel costs for U.S. air carriers by nearly \$200 million. This issue can be alleviated by efficiencies in airspace and procedures.



Photo courtesy of Eclipse Aviation

VLJs can take off from runways as short as 3000 ft., cruise at speeds of 375 kts, and soar to 41,000 ft. These aircraft can utilize more than 5,000 runways in the United States



The FAA is addressing key issues of handling UAS operations in the NAS including, where and how frequently these flights will occur, how they will interact with the ATM system, and how these flights will be segregated.



FAA's plan for future air traffic controller staffing and training

The anticipated growth and complexity in the air transportation system will result in increased flight delays, schedule disruptions, choke points, inefficient flight operations, and passenger inconveniences. Without certain improvements, the FAA operations costs will continue to increase. The air transportation system needs improvements that will leverage current and evolving capabilities in the near term, while building the foundation to address the future needs of the aviation community stakeholders.

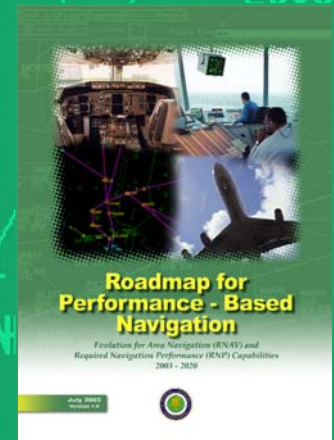
Call to Action

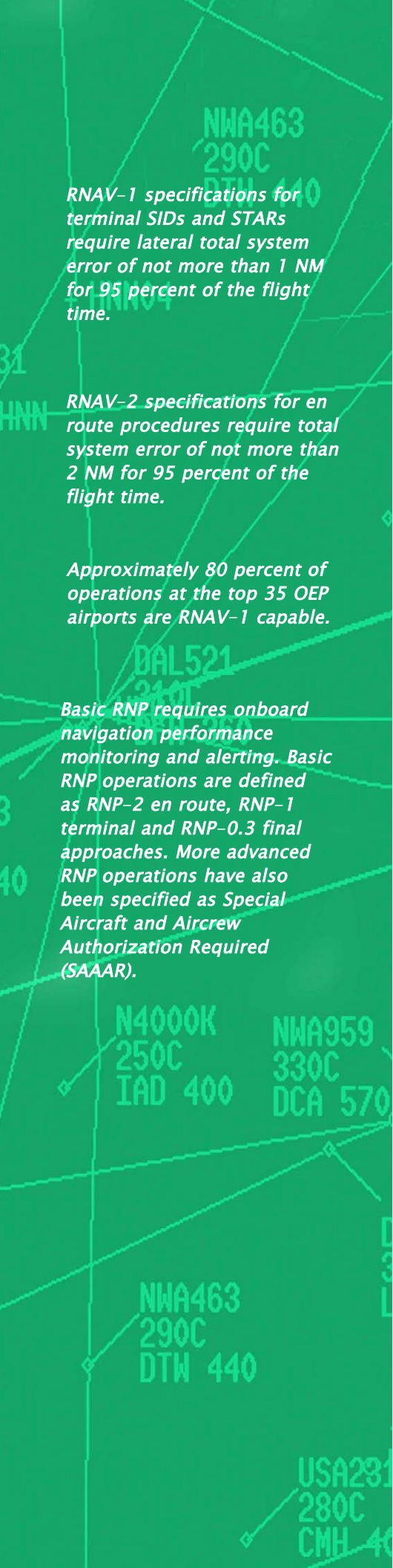
In response to the challenges facing the air transportation industry, the FAA unveiled its commitment to implement performance-based navigation in July 2003. This commitment was outlined in the *Roadmap for Performance-Based Navigation*, and served as a call to action for FAA and industry to implement performance-based navigation. Performance-based navigation is being implemented to increase safety, efficiency and capacity in the NAS, which are critical initiatives to accommodate the expected growth and complexity over the next two decades. This updated 2006 *Roadmap* is a result of collaborative FAA and industry efforts that establish a joint government/industry strategy for implementing performance-based navigation.

This *Roadmap* update reflects a performance-based navigation strategy that has three key features:

- ❑ Expediting the development of performance-based navigation criteria and standards, implementing airspace and procedure improvements in the near term, providing benefits to operators who have invested in existing and upcoming capabilities.
- ❑ Establishing target dates for the introduction of navigation mandates for selected procedures and airspace, with an understanding that any mandate will need to be rationalized based on benefits and costs.
- ❑ Defining new concepts and applications of performance-based navigation for the mid term and far term, with synergy and integration of other capabilities toward the realization of the next generation air transportation goals.

Since the publication of the *Roadmap* in 2003, the FAA and the aviation community have made measurable progress in implementing the goals of the first edition of the *Roadmap*. The progress has included beneficial RNAV and RNP procedures in the NAS, criteria and standards, and development of future concepts. This update to the *Roadmap* defines new commitments and strategies.





RNAV-1 specifications for terminal SIDs and STARs require lateral total system error of not more than 1 NM for 95 percent of the flight time.

RNAV-2 specifications for en route procedures require total system error of not more than 2 NM for 95 percent of the flight time.

Approximately 80 percent of operations at the top 35 OEP airports are RNAV-1 capable.

Basic RNP requires onboard navigation performance monitoring and alerting. Basic RNP operations are defined as RNP-2 en route, RNP-1 terminal and RNP-0.3 final approaches. More advanced RNP operations have also been specified as Special Aircraft and Aircrew Authorization Required (SAAAR).

Performance-Based Navigation and its Benefits

Performance-based navigation is a framework for defining a navigation performance specification along a route, procedure or in airspace within which the aircraft operating must comply with specified operational performance requirements. The aviation stakeholder community has agreed on specifications for RNAV and RNP under this framework. This Roadmap provides an update on these specifications.

Aircraft navigation has long been defined by the location of ground-based navigation aids (NAVAID), which restricted aircraft paths or airspace. With **RNAV** operations, the requirement for a direct link between aircraft navigation and a navigation aid is removed, thereby allowing aircraft better access and flexibility of point-to-point operations, not restricted by the location of ground-based NAVAID infrastructure.

With **RNP** operations, the requirement for onboard performance monitoring and alerting is introduced. A critical characteristic of RNP operations is the ability of the aircraft navigation system to monitor its achieved navigation performance, and to indicate for the crew whether the operational requirement is not being met during an operation. This onboard monitoring and alerting capability enhances pilot situation awareness and can enable closer route spacing without additional air traffic control intervention.

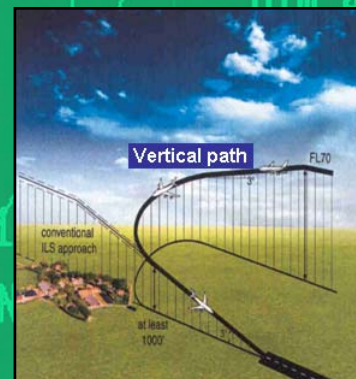
Performance-based navigation provides a simple basis for the design and implementation of complex, automated flight paths. It also affords a basis for airspace design, aircraft separation, and obstacle clearance. Performance-based navigation provides a simple means to communicate the performance and operational capabilities necessary for the utilization of such paths and airspace. Once the performance level (i.e., the *accuracy value*) is determined based on the operational needs, the capability of the aircraft determines whether the specified performance is safely achieved and whether the aircraft qualifies for the operation. The FAA and industry have defined RNAV and RNP specifications that can be satisfied by a range of navigation systems.

Approximately 80 percent of operations at the top 35 OEP airports are estimated to be RNAV-1 capable, with this percentage predicted to increase to over 90 percent by 2010. Approximately 50 percent of transport-category aircraft are capable of basic RNP operations, and 25-30 percent of transport-category aircraft are capable of RNP Special Aircraft and Aircrew Authorization Required (SAAAR) approach operations. Industry-wide forecasts predict 80-90 percent of transport-category aircraft to be capable of basic RNP operations by 2017. Many business aviation aircraft are also capable of RNAV and basic RNP operations (approximately 75 percent being GPS-equipped). Some piston aircraft are RNAV and basic RNP capable, with nearly half of all GA IFR aircraft equipped with IFR-certified GPS navigation systems. Approximately 4000 GA aircraft are capable of approach procedures that utilize the GPS Wide Area Augmentation System (WAAS). Many new transport-category aircraft are being delivered today with capability for Ground-Based Augmentation System (GBAS) Landing System (GLS), with retrofit packages available for existing aircraft as well.

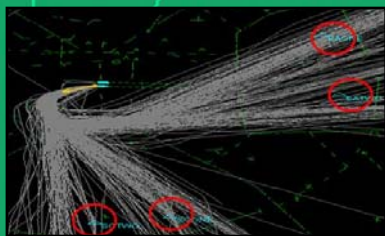
RNAV and RNP specifications facilitate more efficient airspace and procedure design, which collectively result in improved safety, access, capacity, predictability, operational efficiency, and environmental effects. Specifically, RNAV and RNP may enable many benefits:

- ❑ **Increase safety** using three-dimensional (3D) approach operations with course guidance to the runway, that **reduce the risk of controlled flight into terrain (CFIT)**.
- ❑ **Improve airport and airspace access** in all weather conditions and the ability to meet environmental and obstacle clearance constraints through the application of optimized RNAV and RNP operations.
- ❑ **Enhance reliability, repeatability and predictability** of operations, leading to increased throughput. More precise arrival, approach and departure procedures will reduce flight time variability and facilitate smoother traffic flows.
- ❑ **Reduce delays** at airports and in busy airspace through the application of new parallel routes; newly enabled arrival and departure corridors around busy terminal areas; improved flight re-routing capabilities, making better use of optimally spaced procedures and airspace; and de-conflicting adjacent airport flows.
- ❑ **Improve efficiency and flexibility**, by increasing use of **operator-preferred trajectories** NAS-wide, at all altitudes.
- ❑ Promote design and use of **environmentally beneficial arrival and departure corridors** that allow the Flight Management System (FMS) to manage flight performance (climb, descent, and engine performance) as well as time of arrival at key locations. Benefits include **reduced fuel emissions** and more acceptable noise footprints.
- ❑ **Reduce workload and improve productivity** of air traffic controllers, improve pilot and air traffic controller safety through reduced voice communications.

Performance-based navigation will enable the needed operational improvements by leveraging current and evolving aircraft capabilities in the near-term that can be expanded to address the future needs of NAS stakeholders and service providers.

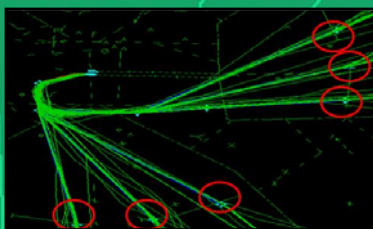


3D operations are defined by a series of points consisting of latitude, longitude and altitude. The operation may also specify a vertical path angle.



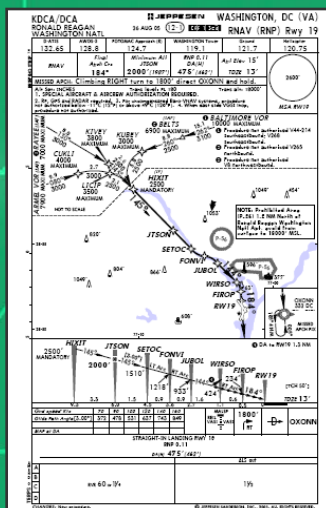
Before RNAV

Departure operations at Hartsfield-Jackson Atlanta International Airport with RNAV SIDs provide an increased number of departure fixes for improved throughput and flexibility.



After RNAV

RNAV SIDs when fully implemented at both Atlanta and Dallas-Ft. Worth are estimated to provide a combined total of approximately \$50 million annually.



RNP SAAAR approach into Washington, DC's Ronald Reagan National Airport.

Key Accomplishments

This section outlines the key accomplishments that have been made in accordance with the *Roadmap*. These accomplishments are summarized in three categories: (a) Implementation of new procedures and capabilities, (b) Development and publication of enabling criteria and standards, and (c) international harmonization. The FAA and industry collaborated step-by-step to successfully deliver these implementations; nevertheless, these accomplishments have not been without challenges. The challenges involved technical, operational and human factors issues. As part of the implementation, extensive lessons learned have been collected and integrated into criteria and guidance material.

Noteworthy of highlighting are the accomplishments in 2005 resulting in published RNP SAAAR approach criteria, and the aircraft and operator approval guidance for RNAV and RNP SAAAR. Of the implementations that are now providing most significant benefits to operators are the RNAV procedures at Dallas-Ft. Worth and Atlanta, as well as the RNP SAAAR approaches at Washington DC's Ronald Reagan National Airport and Alaska Airlines' *special* RNP SAAAR approach procedure into Palm Springs.

SUMMARY OF KEY IMPLEMENTATIONS

- ❑ 169 RNAV SIDs and STARs at 83 airports in the NAS (19 RNAV STARs, 150 RNAV SIDs, plus four helicopter RNAV procedures at four sites)
- ❑ 6 RNP SAAAR approaches, an additional 10 designed and submitted for publication, 15 more in development
- ❑ 21 en route RNAV (charted as "Q") routes and four RNAV IFR terminal transition (charted as "T") routes
- ❑ Florida Airspace Optimization involving 900 new routes, including revisions to coded departure routes to utilize new RNAV STARs
- ❑ Pacific Oceanic 50 NM lateral separation standard, based on RNP-10¹ accuracy
- ❑ RNAV approaches (LNAV/VNAV) to over 800 runway ends
- ❑ 400 new RNAV approaches with LPV minimums
- ❑ First U.S. operational approvals for RNP SAAAR, and aircraft approval for GLS

NEW CRITERIA, STANDARDS AND TOOLS

- ❑ Order 8260.50, *U.S. Standard for WAAS LPV Approach Procedure Construction Criteria*
- ❑ Order 8260.51, *U.S. Standard for Required Navigation Performance (RNP) Instrument Approach Procedure Construction*
- ❑ Order 8260.52, *U.S. Standard for Required Navigation Performance (RNP) Approach Procedure with Special Aircraft and Aircrew Authorization Required (SAAAR)*
- ❑ Order 8260.53, *United States Standard for Instrument Departures that use Radar Vectors to Join RNAV Routes*

¹Oceanic RNP-10 is a 10-NM cross-track accuracy requirement based on ICAO regional supplementary procedures Doc 7030/4 PAC/RAC, Part 1, Chapter 6.

- ❑ Order 7470.1, *DME/DME Evaluation*
- ❑ Order 8260.44A, *Civil Utilization Of Area Navigation (RNAV) Departure Procedures*
- ❑ Notice 8000.300, *Required Navigation Performance (RNP) Airworthiness Approval, Operational Approval, and Design Guidelines for Special Aircraft and Aircrew Authorization Required (SAAAR) Approach Procedures*
- ❑ Notice 8000.302, *Stand-Alone Area Navigation (RNAV) Transition Procedures*
- ❑ AC 20-153, *Acceptance of Data Processes and Associated Navigation Databases*
- ❑ AC 90-96A, *Approval of U.S. Operators and Aircraft to Operate Under Instrument Flight Rules (IFR) in European Airspace Designated for Basic Area Navigation (B-RNAV) and Precision Area Navigation (P-RNAV)*
- ❑ AC 90-100, *U.S. Terminal and En Route Area Navigation (RNAV) Operations*
- ❑ AC 90-101, *Approval Guidance for RNP Procedures with SAAAR*
- ❑ Terminal Area Route Generation, Evaluation, and Traffic Simulation Tool (TARGETS)
- ❑ RNAV-PRO™ DME Screening Tool
- ❑ Aeronautical Information Manual Revisions for RNAV
- ❑ Charting Specifications for RNAV routes and procedures

INTERNATIONAL HARMONIZATION

The FAA is currently pursuing harmonization through a series of bilateral and multilateral collaborations. These collaborations are highlighted below:

- ❑ A new effort aimed at harmonization of performance-based navigation across North American airspace is underway, under the auspices of the North American Aviation Trilateral (NAAT). The NAAT is comprised of the leaders of the FAA, Transport Canada, and Mexico's Directorate General of Civil Aviation. NAV CANADA (Canada's air navigation service provider) and SENEAM (the Mexican Air Navigation Services provider) have been included as partners in the NAAT's efforts towards harmonization of performance-based navigation in North America.
- ❑ The FAA and EUROCONTROL have completed a project to harmonize their respective requirements for RNAV, as contained in FAA AC 90-100 and Joint Aviation Authorities (JAA) Temporary Guidance Leaflet (TGL)-10. This harmonization activity resulted in a recommendation in June 2005 to ICAO for ICAO RNAV-1 and RNAV-2 navigation specifications.
- ❑ The FAA maintains a regular dialogue with Australia's Civil Aviation Safety Authority (CASA) as both States develop standards and implement RNAV and RNP in their national airspace systems. This dialogue is a valuable adjunct to the formal harmonization activities both States engage in through ICAO.
- ❑ The FAA has extensive efforts underway with General Administration of the Civil Aviation of China (CAAC) to assist in their implementation of RNAV and RNP in the People's Republic of China.



Pictured here are the NAAT representatives, from left to right, Agustín Arellano (Director General, Los Servicios a la Navegación en el Espacio Aéreo Mexicano (SENEAM)), Gilberto López Meyer (Director General, Civil Aviation, Mexico), Marion Blakey (Administrator, Federal Aviation Administration), Merlin Preuss (Director General, Safety and Security, Transport Canada), Kathy Fox (Vice-President, Operations, NAV CANADA)



North American Aviation Trilateral Statement on Joint Strategy for Implementation of Performance-Based Navigation: Area navigation (RNAV) and Required navigation Performance (RNP) in North America.



- ❑ The FAA has worked with the Japan Civil Aviation Bureau (JCAB) on the technical aspects of RNAV implementation. JCAB published an RNAV Roadmap for Japan in April 2005. The FAA participates in informal air traffic groups with Japan in the Informal Pacific ATC Coordination Group (IPACG); with New Zealand, Australia, Tahiti, and Fiji in the Informal South Pacific ATS Coordinating Group-ISPACG; and with Russia in the Russian American Coordinating Group for AT (RACGAT) to further expand implementation of RNP-10 and RNP-5 in Pacific oceanic airspace.

A key harmonization activity by FAA and U.S. industry is their participation in ICAO's Required Navigation Performance and Special Operational Requirements Study Group (RNP-SORSG). This group is charged with producing the *Performance-Based Navigation Manual*. Significant ICAO harmonization activities are highlighted below:

- ❑ The FAA and EUROCONTROL coordinated on development of a harmonized RNAV standard for terminal area operations. The new standard, for RNAV-1 and RNAV-2, will be included in the new *Performance-Based Navigation Manual* and is reflected throughout this update to the *Roadmap* as the U.S. transitions to align with the international specification. The transition is expected to be complete with the publication of AC 90-100A.
- ❑ The FAA, with the support of industry and numerous States who are implementing RNP operations, has submitted U.S. procedure design criteria for RNP approaches to ICAO. These criteria, originally developed with industry and international experts' participation, uses values between RNP-0.3 and RNP-0.1, and has been submitted to the ICAO Obstacle Clearance Panel (OCP) for adoption in ICAO Document 8168, *Procedures for Air Navigation Services - Aircraft Operations* (PANS OPS). Adoption of RNP Approach (Authorization Required) criteria by ICAO is expected in 2007.
- ❑ The FAA has submitted elements of the U.S. aircraft and operator requirements for RNP Approach (Authorization Required) to the ICAO RNP-SORSG, for inclusion in the *Performance-Based Navigation Manual*, expected in 2006.
- ❑ ICAO, with support from the FAA, is developing international guidance and specifications for the standard RNP-2, RNP-1 and RNP-0.3 operations discussed in this Roadmap. These specifications will be published in the *Performance-Based Navigation Manual*.

The FAA will also work through its membership in ICAO regional forums, such as the Planning and Implementation group for the Caribbean and South America (CAR/SAM) Regions (GREPECAS) and Regional ICAO groups such as North Atlantic Systems Planning Group (NAT SPG) and Asia Pacific Air Navigation Planning and Implementation Regional Group (APANPIRG), to share expertise, lessons learned, and plans for performance-based navigation.

Overview of the Roadmap

The *Roadmap* is divided into three timeframes: **near term** (2006-2010), **mid term** (2011-2015), and **far term** (2016-2025). The near term focuses on realizing the value of investments by operators in current aircraft and new aircraft acquisitions, as well as investments by FAA in satellite-based navigation and conventional navigation infrastructure. The near term focuses on wide scale RNAV implementation, and includes the introduction of RNP for en route, terminal and approach procedures. The mid term focuses on shifting to implement predominantly RNP operations for improving flight efficiency, airport access and other benefits. The mid term strategy employs RNAV extensively, to improve flight operations NAS-wide. The far term focuses on achieving performance-based operations in the NAS, with integrated RNP, RCP, RSP and RTSP; optimized airspace; automation enhancements; and CNS infrastructure modernizations. The details of the infrastructure modernization are provided separately in the FAA's *Navigation Evolution Roadmap* and other infrastructure roadmaps.

Near Term (2006-2010)	Mid Term (2011-2015)	Far Term (2016-2025)
<p>En Route</p> <ul style="list-style-type: none"> <input type="checkbox"/> RNAV Q Routes <input type="checkbox"/> RNP-2 Routes where beneficial <input type="checkbox"/> T routes and Lower MEAs <input type="checkbox"/> FAA automation and aircraft requirements for enabling RNP with 3D and time of arrival control <p>Oceanic</p> <ul style="list-style-type: none"> <input type="checkbox"/> RNP-10 and 50/50 NM lat/long Pacific <input type="checkbox"/> RNP-10 and 60 NM lat in WATRS <input type="checkbox"/> RNP in Pacific, NAT <input type="checkbox"/> Route spacing standards based on RNP(x) <p>Terminal</p> <ul style="list-style-type: none"> <input type="checkbox"/> RNAV SIDs/STARs at OEP airports <input type="checkbox"/> RNP-2/1 SIDs/STARs where beneficial <input type="checkbox"/> RNAV merging and spacing tools and aircraft requirements for 3D, time of arrival control <p>Approach</p> <ul style="list-style-type: none"> <input type="checkbox"/> At least 25 RNP SAAAR per year <input type="checkbox"/> 300 RNAV (GPS) per year <input type="checkbox"/> Standards for closely spaced and converging runway operations based on RNP(x) 	<p>At end of mid term mandate RNP-2 at and above FL290 At the end of mid term mandate RNAV at and above FL180</p> <p>En Route</p> <ul style="list-style-type: none"> <input type="checkbox"/> Flexible RNP-2/1 routes <input type="checkbox"/> T routes and Lower MEAs <input type="checkbox"/> RNAV and RNP-2/1 with 3D and time of arrival control <p>Oceanic</p> <ul style="list-style-type: none"> <input type="checkbox"/> Expand 30/30 separation in Pacific and NAT MNPS <input type="checkbox"/> Limited RNP-4 and 30 NM lat in WATRS <p>At end of mid term mandate RNAV for arriving/departing at OEP Airports</p> <p>Terminal</p> <ul style="list-style-type: none"> <input type="checkbox"/> RNAV operations at all OEP airports <input type="checkbox"/> RNP 2/1 SIDs/STARs where beneficial <input type="checkbox"/> Airspace Redesign, Procedures for RNAV and RNP with 3D and time of arrival control <p>Approach</p> <ul style="list-style-type: none"> <input type="checkbox"/> At least 25 RNP SAAAR per year <input type="checkbox"/> Several hundred RNAV (GPS) or RNP per year <input type="checkbox"/> Closely spaced parallels and converging runway operations based on RNP(x) 	<p>Performance-Based NAS Operations</p> <ul style="list-style-type: none"> <input type="checkbox"/> RNP Airspace at and above FL290 <input type="checkbox"/> Separation assurance through combination of ground and airborne capabilities <input type="checkbox"/> Strategic and tactical flow management through system-wide integrated ground and airborne information system <input type="checkbox"/> System flexibility and responsiveness through flexible routing and distributed decision-making <input type="checkbox"/> Optimized operations through integrated flight planning, automation and surface management capabilities <p>During the far term mandate RNP in busy en route and terminal airspace</p> <p>During the far term RNAV required elsewhere</p>



The key transition challenges are:

- ☐ To define and adopt a **national level policy enabling additional benefits** based on RNP and RNAV
- ☐ To identify operational and integration issues between navigation and **surveillance, air-ground communications**, and automation tools that maximize the benefits of RNP
- ☐ To support **mixed operations** throughout the term of this Roadmap, in particular considering **navigation system variations** during the near term until appropriate standards are developed and implemented
- ☐ To initiate **rulemaking for mandates** 7-10 years in advance
 - ☐ For civil operations of military aircraft supporting DoD missions, the FAA will develop the needed policies to accommodate the unique mission and capabilities of military aircraft operating in civil airspace
- ☐ To specify needs for **navigation system infrastructure** and ensure funding for managing/transitioning these systems
- ☐ To **harmonize** the evolution of capabilities for interoperability across airspace operations
- ☐ To increase emphasis on **human factors**, especially on training and procedures as operations increase reliance on appropriate use of flight deck systems
- ☐ To facilitate and advance environmental analysis efforts required to support the development of RNAV and RNP procedures
- ☐ To maintain consistent and harmonized global standards for RNAV and RNP operations

Near Term (2006-2010) Priorities

The near term strategy will focus on expediting the implementation and proliferation of RNAV and RNP procedures in the NAS, using the increasing navigation capabilities in the inventory. As air travel demand continues to be sustained at healthy levels, choke points are expected, and delays at the OEP 35 airports will continue to climb. Implementation of RNAV and RNP procedures will help alleviate those issues. The fleet at the OEP airports reflects an average of 80 percent RNAV capability and this is expected to reach over 90 percent by the end of the near term. Continued implementation of beneficial RNAV and RNP procedures in the NAS will not only provide benefits and savings to the operators but also help encourage further equipage. Additionally, key FAA and industry initiatives will be underway to pave the road for mid-term and far-term capabilities.

EN ROUTE OPERATIONAL CAPABILITIES AND MILESTONES

For airspace and corridors requiring structured routes for flow management, RNAV routes (charted as Q routes) will be established. Between busy airports, Q routes provide efficient flows, with limited entry and exit points, like “express lanes” on the highway. Parallel Q routes will be established necessary to meet increasing traffic levels. The FAA will publish 24 new Q routes primarily in the west and southwest U.S. in 2006. During the near term, airspace redesign will extend into the Southeastern U.S., and Non-Restrictive Routing (NRR) operations will be based on the National Reference System (NRS)².

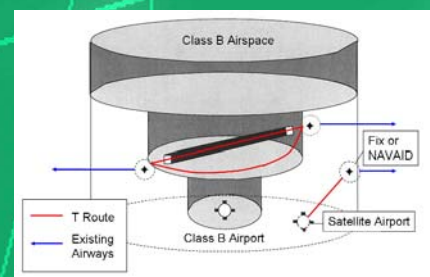
The FAA will implement RNP-2 and RNP-1 routes to enable reduced route spacing (e.g., in non-radar areas) for increased capacity, flexibility and weather avoidance. RNP-1 route implementation is intended to provide reduced en route track spacing (potentially as close as 4 NM between track centerlines), but will be limited to airspace where sufficient aircraft capability exists and where procedures and automation tools support these operations. Where new automation is required for improved traffic flow management, dynamic rerouting, and conflict probe of RNP-2 and RNP-1 routes, these requirements will need to be identified and validated in the near term, and implemented in the mid term.

To benefit GA operators, the FAA is implementing low altitude RNAV routes (published as T-routes). T-routes are being implemented in selected terminal areas to allow aircraft to transit Class B and C airspace more efficiently than the existing paths that rely on ground based NAVAIDS and radar vectoring. In 2006, the FAA will implement 11 new T routes. T routes are also being established in some areas where NAVAID decommissioning has occurred and IFR en route access to key airports in that area becomes limited, e.g., Outer Banks in North Carolina due to NDB decommissioning. In addition, T routes will be evaluated for use along the Gulf Coast and other areas to avoid military use airspace. Where structured routes are not necessary, RNAV-capable GA operators will continue to request and fly direct.

²The NRS is a grid of waypoints overlying the U.S. as the basis for flight plan filing and operations in the redesigned high altitude environment. The NRS provides increased flexibility to en route flight operations and controllers by allowing more efficient tactical route changes that ensure aircraft separation. In the NRR service environment, the user can flight plan the most advantageous path for portions of a proposed route of flight, if the aircraft is RNAV capable.

OEP 35 Airports

Atlanta Hartsfield-Jackson International	ATL
Baltimore-Washington International	BWI
Boston Logan International	BOS
Charlotte/Douglas International	CLT
Chicago Midway	MDW
Chicago O'Hare International	ORD
Cincinnati-Northern Kentucky	CVG
Cleveland-Hopkins International	CLE
Dallas-Fort Worth International	DFW
Denver International	DEN
Detroit Metro Wayne County	DTW
Fort Lauderdale-Hollywood International	FLL
George Bush Intercontinental	IAH
Greater Pittsburgh International	PIT
Honolulu International	HNL
Lambert St. Louis International	STL
Las Vegas McCarran International	LAS
Los Angeles International	LAX
Memphis International	MEM
Miami International	MIA
Minneapolis-St Paul International	MSP
New York John F. Kennedy International	JFK
New York LaGuardia	LGA
Newark International	EWR
Orlando International	MCO
Philadelphia International	PHL
Phoenix Sky Harbor International	PHX
Portland International	PDX
Ronald Reagan National	DCA
Salt Lake City International	SLC
San Diego International Lindbergh	SAN
San Francisco International	SFO
Seattle-Tacoma International	SEA
Tampa International	TPA
Washington Dulles International	IAD



General Aviation community has sought the development of T Routes and lower MEAs to improve routing and safety.



ATOP has been implemented in New York and Oakland Air Route Traffic Control Centers (ARTCC). ATOP Ocean21 system (pictured here) supports reduced separation standards for RNP approved aircraft.

Lowering minimum enroute altitudes (MEA) enabled by GPS improves safety of flight by avoiding icing and turbulence at higher altitudes, and allows maximum use of available airspace. Lower MEAs have been implemented in Alaska with successful safety benefits. Lower MEAs will be established initially along existing IFR airways where benefits are identified and where communication service exists. In 2006, the FAA will establish lower MEAs on five existing IFR airways in CONUS. Lower MEAs may require changes to automation and airspace, in particular when used for area navigation when this becomes necessary for airspace access and improved safety.

OCEANIC OPERATIONAL CAPABILITIES AND MILESTONES

To promote global harmonization of oceanic efficiency gains based on RNP, the FAA continues to work closely with international partners to promulgate reduced oceanic horizontal separation minima between aircraft approved for RNP-10 and RNP-4 operations.

During the near term, the current RNP-10 routes in the Pacific Region will continue, and Oakland Air Route Traffic Control Center (ARTCC) achieves full transition to the Advanced Technologies and Oceanic Procedures (ATOP) Ocean21 system. Ocean21 supports the FANS 1/A automatic dependent surveillance-contract (ADS-C) functionality that is necessary for the automated application of 50 NM longitudinal separation.³ Transition to the Ocean21 automation system in the New York and Oakland ARTCCs enhances ATC capability to support RNP operations through implementation of reduced separation standards for RNP approved aircraft. Anchorage ARTCC is expected to fully transition to Ocean21 for portions of its oceanic airspace in 2007-2008.

The U.S. began using 30 NM horizontal separation between RNP-4 approved aircraft in December 2005 in the South Pacific (SOPAC) between California, and Australia and Asia. With lessons learned from these trials, operational implementation is planned to expand to other oceanic airspace—beginning in the Pacific. The implementation of this reduced horizontal separation for aircraft demonstrating more stringent RNP capability, as well as other Communications, Navigation, Surveillance (CNS) elements, is part of a worldwide ICAO coordinated effort to improve air traffic and air navigation services. The U.S. plans to expand the application of 30/30 to other regions in the Pacific in this timeframe.

The North Atlantic (NAT) ICAO Region has implemented Minimum Navigation Performance Specifications (MNPS) and the FAA is working with both the ICAO NAT and Caribbean Regions to analyze oceanic and offshore airspace in or near the West Atlantic Route System (WATRS). This analysis will include current aircraft operating characteristics and airspace configuration with the intent that RNP-10 can be implemented around the 2007 timeframe. Implementation of RNP-10 in this complex airspace area will permit lateral separation to be reduced from 90 NM to 60 or 50 NM. Both ICAO Regions are supportive of this introduction to RNP-10 in this area. While there may not be benefits to transitioning MNPS airspace north of WATRS to support RNP-10 operations, the NAT is considering the introduction of RNP-4 or RNP-2 in the NAT in approximately 2009.

³Application of 50 NM longitudinal separation for RNP-10 qualified aircraft requires ADS-C position reports at least every 27 minutes, and for RNP-4 qualified aircraft requires ADS-C position reports at least every 32 minutes.

TERMINAL OPERATIONAL CAPABILITIES AND MILESTONES

Usage of RNAV and RNP in the terminal domain is improving airspace design at many of the busiest airports in the U.S. through better use of arrival and departure corridors. It also helps to reduce conflict between traffic flows by consolidating flight tracks. RNAV SID and STAR procedures improve safety, capacity and flight efficiency. For example, these procedures are already reducing controller-pilot communications in Atlanta and Dallas Ft. Worth up to 50 percent, and reduce communication errors by pilots and controllers.

In 2006, the FAA will publish 79 RNAV SIDs and STARs and make associated airspace design changes. The FAA will implement RNAV SIDs and STARs implementation at the OEP airports by the end of the near-term.⁴

In addition, the FAA will implement RNP SIDs and STARs, in certain cases applying advanced RNP functionality such as radius-to-fix (RF) path terminators, to assure repeatable turns where beneficial, and to enable more efficient design of limited airspace.

For RNAV and RNP SIDs, the following implementation strategies have been adopted:

1. Implement RNAV-1 SIDs, for maximum reduction in controller-pilot communications, and for environmental or obstacle clearance requirements.
2. Implement diverging RNAV-1 departure paths where feasible to take advantage of available airspace for maximum runway throughput.
3. Where operationally feasible, implement seamless procedures from RNAV-1 SIDs to en route entry points to achieve smooth transition between terminal and en route RNAV operations.
4. Sequence departures to maximize benefits of RNAV. Identify automation requirements for traffic flow management, sequencing and spacing tools, flight plan processing and tower data entry activities.
5. Implement RNP-1 where RNAV-1 SIDs do not maximize benefits. Implement RNP SAAAR departure procedures where RNP-1 is not feasible.

For RNAV and RNP STARs, the following implementation strategies have been adopted:

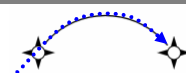
1. For maximum benefit, implement RNAV-1 STAR runway transitions that connect RNAV STARs to a standard instrument approach procedure (SIAP).
2. To enable dual RNAV arrival streams for parallel runway operations, implement RNAV-1 STAR runway transitions that end at a specified point prior to the SIAP.
3. In terminal areas with merging RNAV arrival streams, implement flow management through metering and tactical controller tools that maximize the efficiency and throughput for RNAV arrival operations.
4. Develop operational concepts and specifications for optimizing vertical paths and time of arrival control based on RNAV and RNP procedures.
5. Implement RNP-1 where RNAV-1 STARs do not maximize benefits.

⁴The FAA is currently planning to publish at least 50 RNAV procedures annually to accomplish this milestone.

Airports needing additional capacity by the end of the near term:

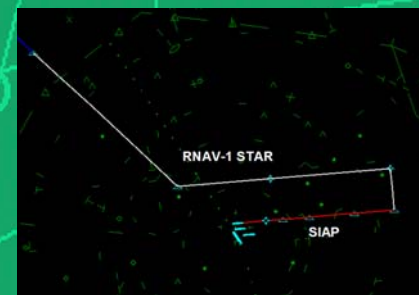
- ❑ Metropolitan Oakland International (OAK)
- ❑ Bob Hope (Burbank, CA) (BUR)
- ❑ Long Beach (LGB)
- ❑ John Wayne-Orange County (SNA)
- ❑ Tucson International (TUS)
- ❑ Albuquerque International Sunport (ABQ)
- ❑ San Antonio International (SAT)
- ❑ Houston Hobby (HOU)
- ❑ *Chicago O'Hare International (ORD)*
- ❑ *New York LaGuardia (LGA)*
- ❑ *New York Kennedy International (JFK)*
- ❑ *Newark Liberty International (EWR)*
- ❑ *Philadelphia International (PHL)*
- ❑ *Palm Beach International (PBI)*
- ❑ *Fort Lauderdale-Hollywood International (FLL)*

Airports in the OEP are italicized.



Radius to a Fix (RF) Path Terminator

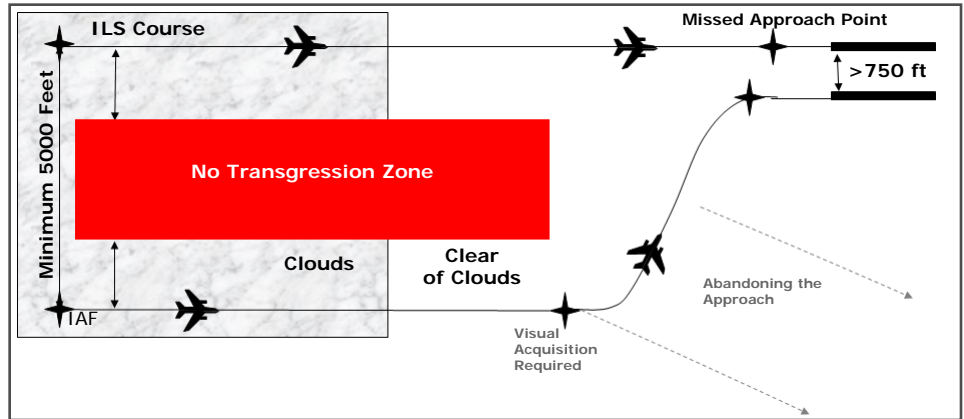
Advanced features such as RF path terminators are utilized to realize beneficial procedures



RNAV-1 STAR connecting to SIAP

APPROACH OPERATIONAL CAPABILITIES AND MILESTONES

Operational changes are required in order to retain capacity as weather deteriorates. This is particularly evident in the approach domain. A means for enabling operational change is to provide instrument approaches to nearly all runways. Another means for improving instrument operations is to de-conflict airport operations, or remove dependencies between operations, enabling more capacity. A particularly useful application is enabling approaches to airports with closely spaced parallel runways, even during reduced visibility conditions.



To achieve optimum runway capacity in low meteorological conditions, runways without an existing instrument procedure are target sites for the publication of RNAV approaches. RNAV approaches include: (a) minimums for WAAS-enabled localizer performance with vertical guidance (LPV), (b) minimums for vertically guided approach services based on lateral navigation/vertical navigation (LNAV/VNAV), and (c) minimums for non-precision approaches based on lateral navigation (LNAV)⁵. RNAV approaches with LPV minimums provide ILS-equivalent capabilities with minimal navigation infrastructure investment. These approaches are being developed by the FAA at a rate of 300 per year.

RNP SAAAR approaches are being developed in the near term to runways requiring features such as RNP less than 0.3, RF legs, and precise, guided turns on the missed approach. The applications for RNP SAAAR instrument approaches are de-confliction of operations between adjacent airports, and improved runway access. The need for RNP SAAAR centers on busy terminal areas where the need for improved access during high traffic demand exists, and where a sufficient percentage of operators are capable of RNP SAAAR. Benefits of RNP SAAAR are to deliver higher capacity and improved arrival efficiency, without disrupting departures and other aspects of operations. The FAA will implement RNP SAAAR approaches (for public use) at a rate of at least 25 per year, with priority of implementation sites being based on close collaboration between FAA and industry. In addition, operators continue to have the option of developing company-specific *special* procedures that are proprietary (not for public use), tailored to the needs of the operator.

Industry has expressed interest in achieving a higher pace of implementation that may be pursued through delegation of procedure development to the private sector. In the near term, the FAA will develop policy for delegation of this authority.

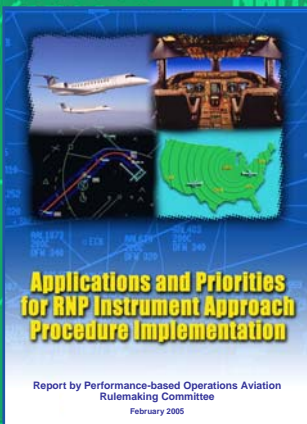
For those airports with existing approach procedures but insufficient airport acceptance rates, other tools and operational implementations are usually required. Complementary airport improvements in runways, markings, lights,

⁵Specifications for construction of LNAV/VNAV and LNAV approaches are soon to be defined based on new and improved standards for RNP-0.3.

RPAT (Parallel Approach Transition)
RNP will improve access to airports with parallel runways (separated by less than 4300 feet). RPAT applies during marginal VMC, when the airport acceptance rate is reduced, due to discontinued use of parallel visual approaches.



Existing terminal automation functionalities are being leveraged to provide merging and spacing tools for the controllers.



A benefits-driven strategy for RNP SAAAR approach implementation

and surveys are necessary to optimize this increasing capability for instrument approach procedures. The FAA and industry are pursuing the use of enhanced flight visibility systems (EFVS) to further improve runway access and evolve to "equivalent visual operations" in IMC. EFVS focuses on the use of advanced sensor technology and head-up guidance systems to provide flight crews the performance necessary for continuing straight-in approach operations beyond existing decision altitudes (as low as 200') down to 100' height above touchdown.

The FAA will also continue the evolution of GBAS⁶ for use in GLS⁷ approach operations to improve access in low visibility conditions (Category I, II and III). GLS will allow for Category I, II and III precision approaches to non-ILS runways where a suitable GBAS is installed. GLS will enhance efficiency and capacity by providing better control over "critical areas" compared with ILS. It will also reduce the reliance on the aging ILS infrastructure.

SUMMARY OF NEAR-TERM (2006-2010) COMMITMENTS

IMPLEMENTATION OF PROCEDURES

- ☐ Completion of RNAV SID and STAR Procedures at the OEP 35 airports
- ☐ Approaches - at least 25 RNP SAAAR, 300 RNAV (GPS) with LNAV, LNAV/VNAV and LPV lines of minima per year, starting in 2006
- ☐ 24 Q routes in 2006
- ☐ RNP routes where beneficial
- ☐ Oceanic RNP combined with other capabilities for reduced separation minima
- ☐ T routes

NEW ENABLING CRITERIA AND STANDARDS

- ☐ Approval Guidance for Basic RNP and Advanced Functionality
- ☐ RNP SIDs and STARs: route design and spacing
- ☐ RNP Approaches: obstacle clearance
- ☐ RNP track separation for radar and non radar
- ☐ Parallel runway operations based on RNAV and RNP

POLICY

- ☐ Policy for beneficial access and service to RNAV and RNP capable aircraft
- ☐ By 2008, issue rulemaking for RNAV and RNP mandates for the mid term
- ☐ Policy for delegation of authority to private sector for development of public procedures

REQUIREMENTS ANALYSIS AND CONCEPT DEVELOPMENT

- ☐ RNP operations in mixed environments
- ☐ Airspace and procedures supporting 3D and controlled time of arrival
- ☐ Flight plan filing and processing for RNP operations
- ☐ Tactical separation tools (e.g., merging and spacing) enabling maximum benefits of RNAV and RNP
- ☐ Converging runway and closely-spaced parallel runway operations based on RNP
- ☐ Coordinate mid term and long term projects implementing inter-dependent systems and technologies (e.g., surveillance)
- ☐ Operational needs for lower RNP values
 - RNP<2 en route, RNP<1 terminal, RNP<0.3 approach

⁶GBAS is a ground-based facility that provides local GPS corrections to onboard receivers. GBAS is currently a research and development (R&D) project for the FAA. The FAA continues to make progress by resolving the integrity risks which pose the largest implementation challenges. By September 2006, the FAA's GBAS Office expects to complete the integrity analysis and implement improved integrity monitoring algorithms in a prototype system that will be used to enable completion of ICAO Standards and Recommended Practices (SARPs) compliance by industry.

⁷GLS is a precision landing operation utilizing GPS signals augmented by a GBAS. The system is intended to provide landing and taxi guidance capability for air carrier operations in low visibility conditions.



The FAA and industry are pursuing use of enhanced flight visibility capabilities to achieve "equivalent visual operations"



Photos Courtesy of the Boeing Company.

GLS will allow for Category II and III precision approaches to non-ILS runways where a suitable GBAS is installed



Mid Term (2011-2015) Priorities

In the mid term, increasing demand for air travel will continue to challenge the efficiencies of the air traffic management system. Nearly 900 million passenger enplanements are projected in 2011, increasing to one billion enplanements by the end of the mid term. Additionally, the emergence of VLJs is expected to create new markets in the general and business aviation sectors for personal, air taxi and point-to-point passenger operations. An estimated 2000 to 2500 VLJs will be operating in the NAS by the beginning of the mid term. Many airports will experience significant increases in unscheduled traffic over the course of the mid term. In addition, many destination airports supporting scheduled air carrier traffic are forecast to grow in popularity (e.g., Las Vegas, Tucson, and Long Beach), and to experience congestion or delays if efforts to increase their capacity are not successful. While the hub-and-spoke system will remain largely the same as today with major airline operations, the demand for more point-to-point service will create new markets. The demand for low cost carriers, air taxi operations and on-demand services will be on the increase. As a result, additional airspace flexibility will be necessary to accommodate not only the increasing growth, but also the increasing air traffic complexity.

The mid term is also characterized by a number of opportunities brought about by the implementation of OEP commitments. The En Route Automation Modernization (ERAM) program will be in place beginning in 2011, providing a platform for advancing en route automation capabilities. Flight planning and flight data processing will be improved to account for navigation capabilities such as RNP-2 and RNP-1 (or lower). The User Request Evaluation Tool (URET) will be improved by this as well, providing better conflict probe and resolution advisories. Center-TRACON Automation System (CTAS) Traffic Management Advisor (TMA) improvements, and Standard Terminal Automation Replacement (STAR) installations, will enable improvements in automation for managing arrivals and departures at many airports. Traffic Flow Management Modernization (TFM-M) capabilities will be in operation, facilitating the smooth flow of traffic even when resources are constrained. Airspace redesign will be based on modernized procedures and standards using RNAV and RNP. Additionally, as a result of an increasingly capable fleet in the inventory, capability to meet RNAV operations reaches 75-90 percent.

The mid term will leverage these increasing flight capabilities based on RNAV and RNP, with a commensurate increase in benefits such as fuel-efficient flight profiles, access to airspace and airports, capacity improvements, and reduced delay. Propagation of equipage and the use of RNP procedures will be expedited by benefits that should provide a competitive advantage over non-RNP operations. To increase operational capacity and efficiency of en route airspace, the FAA is expected to issue a rule to mandate RNP-2 for operations at and above FL290 by the end of the mid term. Mandated use of RNAV-2 for operations at and above FL180 will be in place by 2015 as well. To safely and efficiently manage busy airport arrivals and departures, RNAV-1 will be mandated for arriving and departing OEP airports by the end of the mid term. These mandates are needed to support the increases in traffic demand and complexity, to relieve choke points, and to provide flexible routing options.

To enable maximum benefits of RNP, in particular for optimal routing based on 3D operations and time of arrival control, and for reduction in separation standards, the FAA and industry will pursue use of enhanced communications (e.g., use of

data link for controller-pilot communications⁸) and enhanced surveillance functionality (e.g., Automatic Dependent Surveillance-Broadcast (ADS-B⁹). 3D operations and time of arrival control (as defined by applications and standards in the near term) will be developed and used in the mid term. Upgrades of the flight deck capabilities will be required to enable these benefits in most aircraft, and improvements in ground system automation capabilities will be required also. Development of these capabilities is needed early in the mid term.

Data link will enable complex clearances to be issued easily and without errors. ADS-B will expand or augment surveillance coverage so that track spacing and longitudinal separation can be optimized where needed (e.g., non-radar airspace). Initial capabilities for flights to receive and confirm 3D clearances and time of arrival control based on RNP will be provided in this timeframe. With data link implemented, flights will begin to transmit 4D trajectories (a set of points defined in 4D by latitude, longitude, altitude, and time.) Concepts that leverage this capability will need to be developed. Validating these capabilities and performing trials to demonstrate their effectiveness will be a heavy focus of effort in the mid term. These future concepts will provide maximum operator benefits and will support the progression of NAS evolution into the far term.

EN ROUTE EVOLUTION

RNAV Operations

In the mid term, RNAV will continue to enable use of operator-preferred flight paths, not tied to the location of ground-based NAVAIDs. RNAV-2 operations for flight in positive control airspace (i.e., at or above FL180) is expected to be mandated by 2015. This will enable airspace redesign and route optimization based on RNAV-2 operations.

RNAV operations based on usage of DME/DME/IRU and GPS are expected to continue through the mid term. Conventional routes (Jet routes) that are no longer being used may be eliminated during this time period.

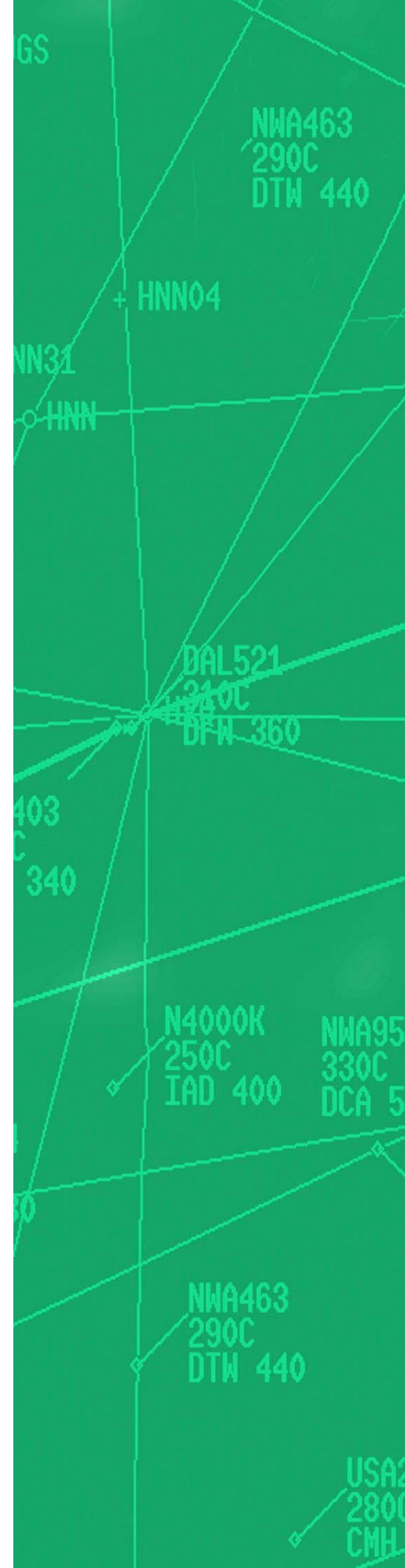
Where structure is needed for routing around and through busy terminal areas, additional T routes will be developed, serving low-altitude operators who operate in close proximity to large airports. This will allow airspace operators (primarily GA) to transition safely around and through busy metropolitan areas predictably and reliably.

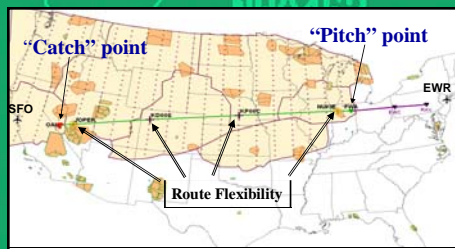
Implementation of RNP-2 and RNP-1

In 2006, operations at and above FL290 comprise over 80 percent of en route operations in the NAS. Traffic in this airspace is expected to increase significantly during the mid term. RNP-2 operations in this airspace will enable more optimal routing and reduced track spacing for managing en route efficiency. Airspace will be redesigned for RNP operations based on consistent, repeatable paths for improved throughput into en route airspace, primarily in the transition sectors from terminal airspace. At the end of the mid term, RNP-2 capability is expected

⁸The FAA's data link efforts are currently focused on an imminent Investment Analysis Readiness Decision by the FAA's Executive Committee in September 2006, followed by a Joint Research Council (JRC) 2A scheduled for March 2007.

⁹The FAA's ADS-B Program underwent a recent decision at the JRC 2B held in June 2006. The next decision point is the JRC 2B2 scheduled for February 2007, which is the final investment decision to determine whether an investment opportunity is approved for funding and implementation of ADS-B.





Shown here are "pitch" and "catch" points for a flight originating in Newark (EWR) and traveling to San Francisco (SFO). After the RNAV equipped flight has departed EWR, it follows structured routing until it reaches its filed "pitch" point (noted by FWA) where the flight enters the Non-Restrictive Routing (NRR) portion of the flight. The aircraft can now fly user-preferred routing until the catch point for its arrival airport. The requirement to file a point in every center is still enforced but the point can be a latitude/longitude, a NAVAID, a waypoint, or a Navigation Reference System (NRS) point (as illustrated in the picture). The flight will be required to return to structured routing once the flight reaches its filed "catch" point (noted by OAL) and will proceed to the SFO terminal to land.



to be mandated for operations at or above FL290 to capture these airspace benefits, for fuel efficient flight profiles, reduced controller workload, and capacity improvements. A mandate would be driven substantially by the growth expectation of airspace operations, and the delivery of clear benefits that outweigh the costs.

Operator-preferred RNP routes will be supported by NRR, where these routes will extend from a departure waypoint (or "pitch" point), through the en route segment, and terminate at an arrival waypoint (or "catch" point). These pitch and catch points will be more flexible and more numerous than today's departure and arrival fixes. As more operators take advantage of NRR, the use of the published route structure will decline. The completion of airspace redesign efforts and the expansion of NRR based on RNP will facilitate the elimination of conventional routes.

At low altitudes within radar coverage, operators will be able to file and fly operator-preferred RNP-2 and RNP-1 where needed throughout the NAS, with benefits even in many congested areas.

Merging of flows, and crossing points, will continue to pose challenges as choke points arise. By applying metering or time of arrival control at catch points for aircraft descending from high altitude airspace, flow management will be improved and will possibly reduce miles in trail (MIT) restrictions into airports. To reduce holding, ground delays, or issuing speed restrictions at existing pitch and catch points, the number of these waypoints will increase using RNP-2, RNP-1 or lower, with associated track separation criteria as needed.

At the end of the mid term, other benefits of RNP will be enabled, such as passing lanes to manage the mix of faster and slower aircraft in congested airspace, and avoiding convective weather or military use airspace through use of low RNP values and narrow routing corridors. In addition, flexible RNP rerouting will be introduced as aircraft become capable of reroutes using fixed radius transitions and RF legs.

Automation for RNAV and RNP Operations

En route automation enhancements will allow the assignment of RNAV and RNP routes based upon specific knowledge of an aircraft's RNP capabilities. With collaborative routing tools, en route automation will assign aircraft priority because en route automation can rely upon the aircraft's ability to change a flight path and safely fly around problem areas. This functionality will allow the controller the ability to recognize aircraft capability and to match the aircraft to dynamic routes or procedures allowing equipped aircraft the ability to maximize their schedule predictability.

Automated conflict detection in most en route airspace will be needed as NRR usage increases. Conflict detection will be improved with path repeatability achieved by RNAV and RNP operations. Midterm automation tools will facilitate the introduction of RNP offsets and other forms of dynamic tracks for maximizing the capacity of airspace. By the end of the mid term, en route automation will evolve to execute problem detection and conformance algorithms that include offset maneuvers (e.g., passing of aircraft and maneuvering around weather).

OCEANIC EVOLUTION

In the mid term, the U.S. will collaborate with international partners as appropriate to expand the application of RNP-10 and RNP-4 supporting 50/50 and 30/30 NM

separation minima, for qualified aircraft with ADS-C and CPDLC capabilities, to other selected sub regions in the oceanic environment. This effort could yield a seamless oceanic standard across service provider boundaries. Benefits from this will include more direct, wind-efficient routings and greater flight path flexibility.

The benefits and plans for implementing separations below 30/30 NM will be explored in the mid term. In addition, operator-preferred routes and dynamic rerouting will be expanded in the Pacific and implemented in the Atlantic.

TERMINAL EVOLUTION

During this period, RNAV-1 will become a required capability for flights arriving and departing OEP airports. Specific OEP airport mandates will be based upon the needs of the airspace such as the volume of traffic and complexity of operations. This will provide the necessary throughput and access, as well as reduced controller workload while maintaining safety during high traffic demand.

RNAV-1 SIDs and STARs are expected to be implemented at many of the top 100 airports in the NAS, and at satellite airports located within busy terminal airspace. With RNAV-1 operations as the predominant form of navigation in terminal areas by the end of the mid term, the FAA has the option of removing the conventional terminal procedures that no longer are expected to be used.

RNP SIDs and STARs

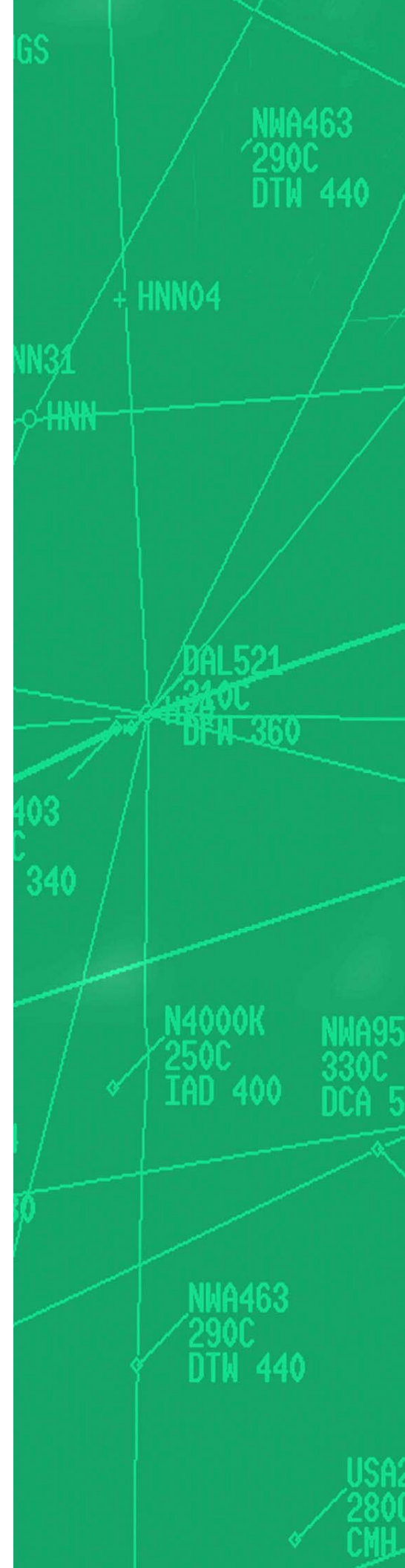
RNP-1 SIDs and STARs will be implemented at all of the nation's busiest airports to provide de-confliction of tracks, and flows with optimal spacing. RNP-1 SIDs will enable consistent, predictable flight tracks, and additional egress routes for higher throughput to mitigate delays. RNP-1 STARs will connect to approaches using 3D operations and time of arrival control as appropriate, to provide arrival efficiency. Trials that combine data link and enhanced automation capabilities to achieve improved strategic management for sequencing and spacing will be conducted in the mid term.

RNP SIDs and STARs based on lower RNP values will be implemented as necessary to achieve closer track spacing and other benefits where aircraft capabilities exist. Curved parallel paths, for both departures and arrivals, will be pursued in this timeframe for higher throughput and runway utilization at airports with parallel runways.

Terminal Automation

Terminal automation will be enhanced with merging and spacing tools to manage complex flows into busy terminal areas, providing the greatest benefits to aircraft with the most advanced capabilities. Flights departing busy airports will be sequenced in a more optimal way than today, based on better data processing by flow management tools, and based on better flight plan filing. Flights arriving and departing busy terminal areas will follow ATC-assigned RNP routes. Applications and benefits of downlinking an aircraft's 4D trajectory will be developed and validated so intent can be automatically monitored and used in conflict prediction/resolution for terminal operations.

RNAV and RNP operations will evolve to include tactical maneuvering for the purpose of spacing, primarily for arrivals into busy airports. Terminal automation will evolve to provide controllers with advisories on the need for these tactical maneuvers, such as a flight path offset to generate more separation from a leading aircraft.





Curved parallel RNP routes onto final approach.

RNAV and RNP operations are also expected to include Time of Arrival Control, which leverages FMS estimates of the time of arrival of an aircraft at upcoming waypoints on the route based on the planned path, current airspeed, wind estimates, altitude and speed constraints at waypoints.

APPROACH CAPABILITY EVOLUTION

Implementation priorities for instrument approaches in the mid term will continue to be based on RNAV and RNP. The FAA will continue to add RNAV approaches with LPV minimums at a rate of 300 or more per year. The implementation of RNP SAAAR approaches will continue at a faster pace than in the near term, with at least 50 RNP SAAAR approaches implemented per year, as processes for developing approaches become streamlined or are delegated. RNP SAAAR approach procedures will lay the foundation for separation reductions, and maximizing throughput to parallel runways and to converging runways.

To achieve reduced separations and improved capacity, RNP SAAAR approach procedures will leverage enhanced surveillance capabilities. Use of flight deck automation that meets the requirements for aids to visual acquisition with suitable performance/integrity (e.g., cockpit display of traffic information with position/state information about proximate traffic) may be an option for this timeframe.

The implementation of GLS and other new types of procedures based on private GBAS installations, is planned by some industry stakeholders in this timeframe.

Benefits of enhanced flight visibility are expected to increase in this timeframe as operators pursue additional taxi, take-off and landing applications along with approach applications.

SUMMARY OF MID-TERM (2011-2015) COMMITMENTS

IMPLEMENTATION OF PROCEDURES AND AIRSPACE

- ☐ RNP-2 required operations at and above FL290
 - Lower RNP available where needed for benefit
- ☐ RNP-2 available, RNAV-2 required operations at and above FL180
 - Lower RNP available where needed for benefit
- ☐ RNP-1 available, RNAV-1 required for arriving and departing all OEP Airports
 - Lower RNP available where needed for benefit
- ☐ NRR expansion, automation for optimizing RNAV and RNP, beneficial 3D and controlled time of arrival operations
- ☐ Oceanic RNP combined with other capabilities for reduced separation minima (30/30)
- ☐ T routes
- ☐ Approaches (at least 50 RNP SAAAR, 300 LPV per year; introduction of GLS approaches)

ENABLING CRITERIA AND STANDARDS

- ☐ Standards for integrated RNP, RSP, RCP
- ☐ Conventional Route elimination criteria
- ☐ Equivalent Visual Operations criteria

POLICY

- ☐ Rulemaking for all mandates
- ☐ Enhanced flight visibility for take off, taxi, landing

REQUIREMENTS ANALYSIS AND CONCEPT DEVELOPMENT

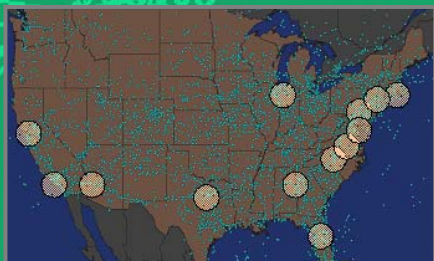
- ☐ Procedures and automation for integrating RNP, RCP, RSP
- ☐ Enhanced traffic flow management tools
- ☐ Procedures and automation for integrated flight planning, routing, sequencing

By end of mid term:

- *Mandate RNP-2 for operations at or above FL290*
- *Mandate RNAV-2 for operations at or above FL180*
- *Mandate RNAV-1 SIDs and STARs for arriving/departing OEP Airports*

- ❑ Ontario International (ONT)
- ❑ Las Vegas McCarran International (LAS)
- ❑ Chicago Midway International (MDW)
- ❑ Birmingham International (BHM)
- ❑ Hartsfield-Jackson Atlanta International (ATL)
- ❑ Bradley International (BDL: Windsor Locks, CT)
- ❑ T.F. Green (PVD: Providence, RI)
- ❑ Long Island MacArthur (ISP)
- ❑ Metropolitan Oakland International (OAK)
- ❑ Bob Hope (Burbank, CA) (BUR)
- ❑ Long Beach (LGB)
- ❑ John Wayne-Orange County (SNA)
- ❑ Tucson International (TUS)
- ❑ Albuquerque International Sunport (ABQ)
- ❑ San Antonio International (SAT)
- ❑ Houston Hobby (HOU)
- ❑ New York LaGuardia (LGA)
- ❑ Newark Liberty International (EWR)

Airports in the OEP are italicized.



Numerous OEP airports will exceed their capacity in the far term.



Far Term (2016-2025): Achieving a Performance-Based NAS

The far-term environment will be characterized by continued growth in air travel and an increase in air traffic complexity. In 2016, FAA forecasts suggest that U.S. commercial air carriers will transport that year a total of 1.6 trillion aircraft seat miles (ASM) and more than a billion passengers. Nearly 250 million passengers are projected to fly between the U.S. and the rest of the world, with the largest growth predicted in the Asian, Pacific, and Latin American markets, averaging an annual 5-7 percent growth rate. The hub-and-spoke system is expected to be the primary mechanism for transporting passengers in this timeframe; however, the demand for point-to-point service and on-demand air taxi service is expected to constitute an increasing share of the total market. Socio-economic factors suggest that the majority of point-to-point services will be needed at satellite airports surrounding the busiest metropolitan airports. This growing segment of the market is expected to be served by VLJs and regional jets.

With respect to airport capacity needs, forecasts at more than 200 metropolitan areas in the U.S. in this timeframe suggest that (1) more than 90 percent of the capacity at the OEP 35 airports will be used and (2) numerous other airports are expected to be in need of additional capacity.

No one solution or simple combination of solutions will address the expected inefficiencies, delays and congestion resulting from the growth in air transportation demand anticipated in this timeframe. What is needed is an operational concept that integrates key performance-based elements including RNP, RCP, RSP and RTSP into a unified overall concept towards achieving performance-based operations. Performance-based operations, aligned with future goals of the JPDO, will address the far-term air transportation needs.

The **key strategies** for performance-based operations in the far term employing an integrated set of solutions are as follows:

1. **Separation assurance will remain predominantly a ground-based responsibility, achieved through a combination of ground and airborne capabilities**
 - ❑ Strategic problem detection and resolution through better knowledge of aircraft position and intent information coupled with automated ground-based problem resolution
 - ❑ Improved controller-pilot workload balance substantially reducing voice communication of clearances, through data link of clearances to the flight deck and universal use of RNAV and RNP
 - ❑ Flight deck-based separation assurance in selected situations for tactical and strategic separation assurance including problem detection and resolution.¹⁰

¹⁰Airspace employing this concept has been referred to as "autonomous" airspace.

2. **Strategic and tactical flow management will improve through a system-wide integrated airborne and ground information system**

- ❑ Ground-based system knowledge of real-time aircraft intent with accurate aircraft position and trajectory information available through data link capabilities to the ground automation
- ❑ Real-time sharing of NAS flight demand and other information achieved via ground-based and air-ground communications networks between air traffic management and operations planning/dispatch
- ❑ Improved metering of traffic arriving and departing busy terminal areas

3. Overall system flexibility and responsiveness will be achieved through flexible routing and well-informed, distributed decision-making

- ❑ Leveraging advanced navigation capabilities such as fixed radius transitions, RF legs, and RNP offsets
- ❑ Increased use of operator-preferred routing
- ❑ Increased collaboration between service providers and operators

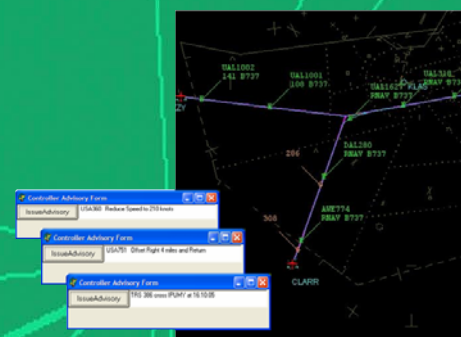
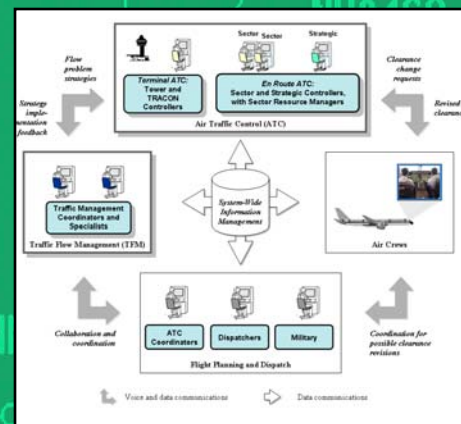
4. **Airport operations at the busiest airports will be optimized through an integrated set of pre-departure planning information, ground-based automation, and surface movement management capabilities**

- ❑ RNP-based arrival and departure structure for greater predictability
- ❑ Ground-based tactical merging and spacing capabilities in terminal airspace
- ❑ Integrated surface movement optimization capabilities to synchronize aircraft movement on the ground
- ❑ Improved meteorological and aircraft intent information shared via data link

Elaboration of Key Strategies

Separation assurance will continue to be the fundamental principle of air traffic management in this timeframe. Into the foreseeable future, separation assurance is expected to remain ground-based and predominantly the responsibility of air traffic control in busy airspace (perhaps even everywhere in the NAS), leveraging automation capabilities on the ground. To a measurable extent, ground automation and flow management tools will be enhanced to manage conflict detection and resolution in a strategic manner; however, it is expected that controllers will retain separation assurance responsibility.

Strategic problem detection and resolution is expected to be achieved through better knowledge of aircraft position and intent information coupled with automated ground-based problem resolution (nominally 20-minute look-ahead time window). In addition, pilot and air traffic controller workload will be reduced by substantially reducing voice communication of clearances, through automated route clearances to the flight deck, and through confirmation (e.g., downlink) of flight intent and other useful information from the flight deck to the ground automation.



Future ground based tactical merging and spacing capabilities include a controller decision support tool capable of providing conflict detection and resolution of well defined traffic flows. This tool will assist the controller with compression management. This tool is intended to be used at merge points and to maintain longitudinal separation between aircraft following in-trail.



With the necessary technology, procedures and training, it may be possible for separation tasks to be delegated to pilots and flight deck systems in certain situations to fully leverage flight deck capabilities (traffic information, airborne separation assurance procedures, and flight deck systems) and to reduce reliance on ground infrastructure, automation and controller workload. Where appropriate, the use of flight deck equipment to provide pilots the “electronic” visual separation and enhanced flight visibility for approaches in low visibility will increase runway capacity and possibly reduce runway occupancy times. With pilot concurrence, ATC will delegate to properly equipped aircraft in IMC the responsibility to separate from other specific aircraft in the sequence. For instance, an aircraft could be instructed to follow a leading aircraft in IMC maintaining a certain distance from the leading aircraft. Once the pilot agreed to do so, responsibility for separation from the leading aircraft would be transferred to the pilot as is now done with visual approaches. Improved wake prediction and notification technologies will lead to reduced separation requirements for aircraft operating to single or multiple runways, given appropriate procedures for delegation. Safety, human factors, and technological studies are underway to further develop this far-term strategy, and to conduct experiments to gain early experience (even benefits).

System-wide information management in the far term will enable real-time data sharing of NAS constraints, airport and airspace capacity, and aircraft performance. Electronic data communications between the ATC automation and aircraft, achieved through data link, will be widespread—possibly mandated in the busiest airspace and airports. The exchange of data directly between the ATC automation and the aircraft flight management system will enable better strategic and tactical management of flight operations.

Aircraft will downlink to the ground-based system their position and intent data, in addition to speed, weight, climb and descent rates, and wind or turbulence reports. The ATC automation will uplink route clearances and other types of information, for example, weather, metering, choke points, and airspace use restrictions.

To ensure predictability and integrity of downlinked trajectories, RNP is planned to become mandatory in busy en route and terminal airspace where benefits will clearly accrue. RNAV operations will be mandatory in all other airspace in the far term. Achieving standardized FMS functionalities and consistent levels of crew operation of the FMS are integral to the success of this far-term strategy. Accomplishing a high level of predictability will require close coordination with industry and manufacturers.

The most highly capable aircraft in the far term will meet requirements for low values of RNP, potentially supporting Category III operations. The most capable flights are expected to benefit in terms of shortest routes during IMC or convective weather, and to transit or avoid constrained airspace. These flights will experience efficiencies and reduced delays operating into and out of the busiest airports.

Time-based metering to terminal airspace will be a key feature of the future flow management initiatives through implementation of sophisticated ground-based automation and use of real-time flight intent. This will improve the sequencing and spacing of flights and the efficiency of terminal operations.

RNP will be used uniformly for arriving and departing busy airports in the far term. Managing high densities of traffic and merging streams will be optimized, and ATC will continue to maintain control over sequencing and separation; however,

aircraft arriving and departing the busiest airports will require little controller intervention. Controllers will spend more time monitoring flows and intervene only as needed, primarily when conflict prediction algorithms indicate a potential problem.

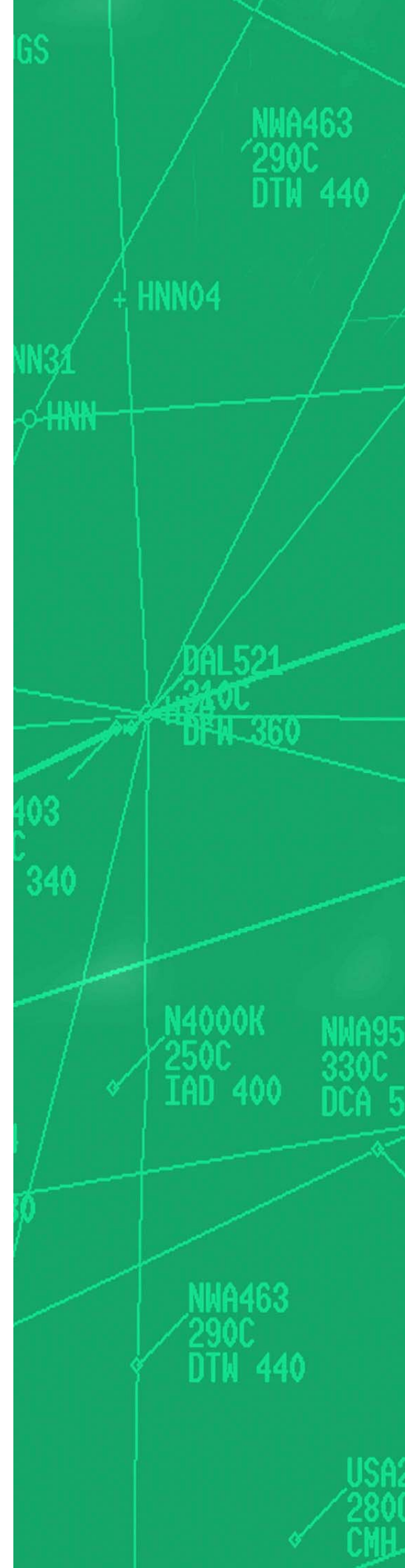
For arrivals and departures at the busiest airports, routing and downlink of aircraft intent based on RNP will provide highly predictable operations. Clearances specifying lateral or 3D paths, and time of arrival control at busy merge points, will be issued prior to arrival or departure, and will be sequenced through advanced metering techniques and integrated arrival/departure planning information. Improved knowledge of meteorological conditions will enable improved flight path conformance, including time of arrival control at key merge points. Terminal arrival and departure management will be improved through RNP, with seamless routing from the en route and transition segments to the runway threshold.

Enhanced surface movement tools will provide surface management capabilities that synchronize aircraft movement on the ground, for example to coordinate taxiing aircraft across active runways and to improve the delivery of aircraft from the parking areas to the main taxiways.

Key Research Areas

A number of key research questions need to be addressed to effectively apply these strategies. A sampling of these key research questions are enumerated below:

- ☐ *What are the FMS requirements to enable the future concepts and applications?*
- ☐ *To what extent can lower RNP values be achieved and how can these be leveraged for increased flight efficiency and access benefits?*
- ☐ *How can time of arrival control be effectively applied to maximize capacity of arrival or departure operations, in particular during challenging wind conditions?*
- ☐ *To enable conflict-free flows and optimal throughput in busy terminal areas, under what circumstances should RNAV be mandated for arriving/departing satellite airports?*
- ☐ *To what extent can lateral or longitudinal separation assurance be fully automated, in particular on final approach during parallel operations?*
- ☐ *To what extent can surface movement be automated, and what are the cost-benefit trade-offs associated with different levels of automation?*
- ☐ *For terminal ATC operations, to what extent can conflict detection and resolution be automated?*
- ☐ *What are the situation awareness requirements for air traffic controllers in case of data link or other failures?*
- ☐ *In what situations is delegation of separation to the flight crews appropriate?*
- ☐ *What level of onboard functionality is required for flight crews to accept separation responsibility within an acceptable workload level?*
- ☐ *How is information security ensured as information exchange increases?*
- ☐ *What are the policy and procedure implications for increased use of collaborative decision making processes between the service provider and the operator?*





- ☐ *To enable real-time flight deck data exchange what are the avionics data base requirements?*
- ☐ *To what extent can airspace be configured dynamically based on predicted traffic demand and other factors?*
- ☐ *What are the separation standards and procedures needed to enable smoother transition between en route and terminal operations?*

The answers to these and other key research questions are critical to achieving the concept of a performance-based NAS. Lessons learned from the near-term and mid-term implementation of the Roadmap are expected to help answer some of these questions. Other questions will be addressed through further concept development, analysis, modeling, simulation and field trials. As concepts mature and key questions are addressed, more detailed implementation strategies and commitments will be developed.